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(54) VALVE AND LUBRICATOR ASSEMBLIES

(71) We, BAKER INTERNATIONAL CORPORATION, a corporation organised and existing under the laws of the State of California, United States of America, now of 500 City Parkway West, Orange, California, 92668, United States of America, formerly of 6023 Navigation Boulevard, Houston, Texas 77001, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to valve assemblies for sequentially permitting and preventing flow of fluid therethrough, a particularly preferred use of the valve assemblies being with subterranean oil or gas wells.

During the drilling, completion, testing and/or workover of a subterranean well at an inland location, it may be necessary to operate equipment, such as a perforating gun or other tool, on a wire or electric line in the well when the well is under pressure. This is achieved by inserting the equipment into a length of production tubing above the well-head, said length of tubing being commonly referred to as a "lubricator". The lubricator is isolated from the portion of the well therebelow by closing a valve, or a series of readily accessable hand manipulated valves, to allow insertion of the equipment therein before the valve or valves are opened to permit flow once again of fluid emerging from the well. On some inland locations, it may be necessary to extend the lubricator as high as 60 feet into the air.

On offshore locations, where space is at a premium and valves are not readily accessable, an inland-type lubricator is not practical. Clearly, use of such a high length of tubing may be hazardous when extending from a floating vessel at an offshore well site. Relative motion between the floating vessel and tubing which is anchored in the well within the sea bed also causes considerable difficulty in manipulation of manual valves.

Most offshore locations, however, utilize a riser extending from the floating vessel to the ocean floor where it is connected to the uppermost portion of a blowout preventer stack. The riser functions as a casing and provides a conduit for mud circulation and isolation of the well from the sea. Indeed, whenever the well is "live", that is capable of flowing, there will be tubing between the floating vessel and the blow-out preventer stack. This tubing would be inside the riser, if a riser is used, and is available for use as a lubricator if provided with a valve. Use of part of the riser as a lubricator eliminates use of tubing extending above the floating vessel and the above-mentioned hazards involved with such use.

In the view of the fact that the lubricator must contain the well pressure, while equipment is inserted therein for subsequent utilization in the well, it is necessary to control the well pressure below the lubricator during this procedure. This is achieved by use of a valve assembly within the lubricator. Some commercial and prior art lubricators contain valve assemblies which automatically open if hydraulic control pressure is lost. This is undesirable because, under certain conditions, if control pressure were lost, a blow-out might result. Other lubricators contain valve assemblies which automatically open if hydraulic control pressure is increased. This is also undesirable because it might again cause a blow-out of the well. Thus, both of these types of prior art valve assemblies are somewhat disadvantageous in that they are affected in their opening of single control pressure, and consequently they are not fail-safe.

The present lubricator overcomes some of the disadvantages of the prior art by utilising a valve assembly which requires a combination of control fluids to be operational before opening, and is thus much less likely to open unintentionally, the term operational in its broadest sense meaning presence or absence of pressure exerted by said control fluids.

According to the present invention, a valve assembly comprises: a passageway to be opened and closed by valve means

sequentially to permit and prevent flow of a fluid therethrough from an upstream side of the valve means to a downstream side of the valve means; means responsive to a first control fluid, which fluid is isolated from fluid in the passageway, for causing or allowing shifting of the valve means from its open position to its closed position, and vice versa; means for mechanically locking the valve means in its closed position to prevent shifting of the valve means to its open position in response to just the first control fluid; and means responsive to a second control fluid for unlocking the locking means, and for then causing or allowing the valve means to be shifted from its closed position to its open position.

Preferably, the pressure exerted by fluid flowing through the passageway on the upstream side of the valve means causes the valve means to be shifted to its closed position when pressure extered by the first control fluid is sufficiently reduced. Moreover, the locking means is preferably unlocked when pressure extered by the second control fluid in the passageway on the downstream side of the valve means is sufficiently increased. Ideally, the second control fluid pressure downstream of the valve means must exceed, or at least equal, pressure upstream of the valve means before the valve means is unlocked from its closed position. If in the above arrangement the pressure downstream of the valve means exceeds the upstream pressure, it may in fact shift the valve means to its open position, after the second control fluid responsive means has unlocked the locking means, even in the absence of sufficient pressure exerted by the first control fluid, the valve means being immediately shifted back to its closed position after equalisation of the pressures thereacross.

Finally, means are preferably provided for indicating whether the valve means is in its open or closed positions, said means including a reference pressure chamber whose volume changes with operation of the first control fluid responsive means.

The reader should note that part of the present disclosure forms the subject of our co-pending patent application no. 8 019 560 (Serial No. 1 594 715) which claims a valve assembly comprising: a passageway to be opened and closed by valve means sequentially to permit and prevent flow of a fluid therethrough from an upstream side of the valve means to a downstream side of the valve means, and a floating differential sleeve which is reciprocable along the length of the passageway on the downstream side of the valve means, the differential sleeve being urged into sealing engagement with the valve means in response to pressure differential across the valve means when the valve means is in its closed position, and the differential sleeve being sealingly disengaged from the valve means in the absence of pressure differential across the valve means when the valve means is in its open position.

A valve assembly according to the present invention, in its preferred use with a lubricator for a subterranean oil or gas well, will now be described, by way of example only, with reference to the accompanying drawings, in which:—

Fig. 1 is a schematic longitudinal view showing a floating vessel and a well blowout preventer stack connected by a tubing string located within a riser pipe and including the present lubricator as a part thereof;

Figs. 2A , 2B and 2C are elongate views, in series of the present lubricator with the valve element shown in its fully opened position, Fig. 2B being a lower continuation of Fig. 2A, and Fig. 2C being a lower continuation of Fig. 2B;

Fig. 3 is an exploded view of the valve element and its adjacent activating components, comprising a valve control strap housing (upper member), a valve control strap (middle member), and the ball element (lower member);

Fig. 4 is a cross-section taken along lines 4-4 of Fig. 2C, showing the ball element within the lubricator in opened position and its inter-relation with the valve activating mechanism;

Fig. 4A is a partial side view of the valve and its activating mechanism, the ball element being shown in open communication with flow passageways above and below the apparatus;

Fig. 5A, 5B, and 5C are longitudinal views of the lubricator with the ball element shown in closed position and the locking mechanism in activated state to prevent control line pressure activation of the ball element to open position, Fig. 5B being a lower continuation of Fig. 5A, and Fig. 5C being a lower continuation of Fig. 5B;

Fig. 6 is a cross-section taken along lines 6 - 6 of Fig. 5C showing the ball element and its adjacent operating mechanism, the valve element being shown in closed position;

Fig. 6A is a partial side view of the valve and its activating mechanism, similar to the view shown in Fig. 4A, the valve mechanism being in closed position in relation to flow passageways above and below the apparatus;

Fig. 7 is a complete cross section of the lubricator taken along lines 7 - 7 of Fig. 5B;

Fig. 8 is a longitudinal sectional view of the central section of the lubricator, showing the collet fingers of the lock mechanism sliding between companion locking surfaces on the valve control mandrel and the latch sleeve during relative longitudinal move-

spoon element 69 at the end thereof for securable engagement with a companion upset 70 along the lock mandrel 4.

Operationally interconnected with the locking latch mechanism 68 is the longitudinally extending tubular locking sleeve 64 open at its upper end 64*a* and receiving within its interior 64*b* the lock mandrel 4 and the locking latch mechanism 68. Along the inwardly facing interior surface 64*b* of the locking sleeve 64 and adjacent the outwardly protruding upset 70 along the lock mandrel 4, when the ball element 1 is in its open position, is a slightly outwardly protruding shoulder 71 for cooperation with the upset 70 on the lock mandrel 4 to engage the outer surface 72 of the collet members 65 in order to resist downward longitudinal movement of the lock mandrel 4 after the ball element 1 has been reciprocated to its fully closed position. The lower section of the locking sleeve 64 serves as an outer housing for a spring 73, which is compressably encircled around the lower portion of the lock mandrel 4, the spring 73 urging the entire locking sleeve 64 in an upward direction, this force being resisted by an outwardly protruding shoulder 74 on the lock mandrel 4 which contacts a resistance block 75 extending from the locking sleeve 64 for engagement with the shoulder 74. A thrust bearing 76 is provided around and below the resistance block 75 for assembly of the springs 73.

As will be described in further detail below and in operational sequence, when the ball element 1 is to be reciprocated to closed position, the lock mandrel 4 will be caused to travel upwardly. The force contained within the compressed spring 73 within the locking sleeve 64 will cause the locking sleeve 64 to travel upwardly. As the inner smooth surface 78 along the spoon 69 of the collet 65 contacts and travels along the upwardly sliding upset 70 on the lock mandrel 4, the collet elements 65 will expand outwardly, and the outwardly and slightly downwardly angled outer surface 79 on the spoon 69 will engage the smooth surface or shoulder 71 along the locking sleeve 64. This position is shown in Fig. 8.

As the lock mandrel 4 continues its upward travel, the shoulder surface 71 on the locking sleeve 64 will momentarily engage the surface 79 on the spoon 69 which affords resistance to further upward travel of the locking sleeve 64. Although the sleeve 64 is thus stabilized against longitudinal movement, the lock mandrel 4 continues upward travel with upset 70 passing upwardly against the surface 78 on spoon 69, until the upset 70 is completely above the surface 78 at which time the collet 65 is urged inwardly to its normally retracted position by the force exerted thereon by shoulder 71 engaging its companion surface 79. The force exerted by the 71, 79 interface will cause the collet elements 65 to collapse and pass under the upset 70 while the upward travel of the lock mandrel 4 continues. The shoulder 71 on the locking sleeve 64 is permitted to force the collet 65 to pass under the upset 70 by means of the upward urging of the locking sleeve 64 afforded by expansion of the spring element 73 as the locking sleeve 64 follows the upward travel of the lock mandrel 4.

When the collet 65 is in its locked position, as shown in Fig. 5B, the ball element 1 will be rotated to its completely closed position and, because of the downward longitudinal resistance afforded by the action of the collet 65 in conjunction with the lock mandrel 4, the lock mandrel 4 will be unable to travel downwardly to reopen the ball element 1.

A series of pressure passages 82 are provided laterally through the locking sleeve 64 to permit transmission of control fluid throughout the control pressure housing immediate the spring 73.

Operatively associated with the locking mechanism of the present apparatus, and as means to reopen the ball element 1 after the lock mandrel 4 has been placed in its fully locked position, a releasing piston mechanism is provided which is initially activated by increasing well tubing pressure within the tubing string I and the interior A-1 of the apparatus A to provide a differential over the well pressure within the pressure chamber areas of the apparatus A. Tubing pressure ports 34 circumferentially extend through the lock piston mandrel 5, which is attached by threads 37 to the lower end of the lock mandrel 4. A releasing piston 36 which is interconnected to the lower end of the locking sleeve 64 defines along its inner surface a piston pressure chamber 35 communicating with the ports 34. The releasing piston 36 being functionally interconnected with the locking sleeve 64 is limited in upward longitudinal travel by contact of the resistance block 75 with the outwardly protruding shoulder 74 along the inner surface of the lock mandrel 4, while resistance to downward longitudinal movement of the releasing piston 36 is afforded by an outwardly extending shoulder 80 thereon which may contact a companion shoulder 81 which extends outwardly along the lock piston housing 54.

As the pressure in the area P^1 is overcome by an increase in the pressure in the area P, differential pressure will cause the expansion of the piston chamber 35, adjacent the releasing piston 36, and the releasing piston 36 with its interconnected locking sleeve 64 will be urged slightly downwardly, thus permitting the outwardly extending and

upwardly facing shoulder 71 on the locking sleeve 64 to be disengaged from its companion surface 79 of the collet 65. In turn, the lock mandrel 4, which is urged downwardly by the operation of the ball spring element 41 circumferentially extending around the lower portion of the ball piston 3, is permitted to travel downwardly when the collet members 65 spring to their disengaged position and away from the upset 70 along the lock mandrel 4. With the collet elements 65 in disengaged position, the spring 41 surrounding the ball piston 3 encourages downward longitudinal movement of the lock mandrel 4 and its associated parts to rotate the ball element 1 to its fully open position.

The lubricator apparatus A of the present invention is made up such that it is an integral part of the tubing string I with sections of tubing string I being connected to it by threaded or other means. The tubing string I is inserted within the riser pipe R and through the blowout preventer B-P, the tubing string I extending through the sea bed B into the well W. The control and reference vent lines 59 and 60 extend from their respective receiving grooves 57 and 61, within the lubricator valve assembly A to a control panel (not shown) on the drill ship, platform, or the like, and the control line pressure is applied to the control line 59 to the lubricator apparatus, as shown in Figs. 2A, 2B and 2C. As pressure is decreased in the control line, well pressure will act to cause the ball piston 3, the lock mandrel 4 interconnected therewith, the lock piston mandrel 5 therebelow, the thrust carriage 6 and the valve control strap 12 to move upwardly, causing the manipulating pin 19 on the exterior 17*a* of the valve control strap housing 17 to travel within its companion manipulating groove 20 causing rotation of the ball element 1 until the secondary surface 14*b* on the valve stop 14 engages the thrust abutment 16 of the ball element 1, at which point the ball element 1 is in its completely closed position. When the ball element 1 is in its fully closed position, the ball control strap 12 is not the upstop for the ball because the floating differential sleeve 31 rises until part thereof 13b' contacts the lower portion 54*a* of the lock piston housing 54. The differential sleve 31 prohibits further longitudinal travel of the ball element 1, thereby providing a metal-to-metal seal between the differential sleeve 31 and the ball element 1. Additionally, the reference vent line 60, will confirm that the ball piston 3 and its interconnected parts have travelled longitudinally upwardly within the lubricator apparatus A, thus indicating and confirming activation of the tool to rotate the ball element 1 to its closed position.

When it is desired to insert production or completion equipment within the tubing string I to perform functions such as perforating and the like, the ball element 1 is rotated to closed position and the tools are inserted through the tubing string I, which is empty or not pressurised, and the lubricator valve assembly A on a wireline, electric line, or the production string (not shown). The ball element 1 is rotated to its closed position by decreasing control pressure, which, in turn, permits the ball piston 3, the lock mandrel 4, the lock piston mandrel 5, the thrust carriage 6 and the valve control strap 12 to travel upwardly. Repeated variations in control pressure will not then affect the closed and locked position of the valve.

As noted above, in conjunction with the step of manipulating the ball element 1 to its fully closed position, there is provided a locking mechanism to ensure that the ball element 1 is maintained in a fully and sealingly closed position. When the control line 59 pressure is reduced, the lock mandrel 4 will travel upwardly and the upset 70 thereon will cause slight outward expansion of the collet elements 65 on the locking latch 68. As the upward travel of the lock mandrel 4 and ball piston 3 continues, the inner surface of the collet elements 65 will travel across the outwardly protruding surface 70*a* of the upset 70, and the collet elements 65 will be urged into a slightly retracted and locked position after the outer surface 65*a* of the collet elements 65 engage the outwardly protruding shoulder 71 along the locking sleeve 64 which will lock the collet 65 below the upset 70 in a position which will prevent downward movement of the lock mandrel 4. The outwardly extending shoulder 71 on the locking sleeve 64 maintains upward force upon the collet element 65 in conjunction with the lock mandrel 4 by the force of the spring 73 housed within the locking sleeve 64. The upset 70 on the lock mandrel 4 is urged into locking position with the collet 65 and the locking sleeve 64 due to the force of the spring 73. Control pressure may be bled off or increased and the valve will remain closed.

With the ball element 1 of the lubricator assembly A rotated to its completely closed position, the well W is shut off therebelow, thus permitting tubing pressure to be bled off above the lubricator, thereby allowing completion or other equipment to be made up within the lubricator section of he tubing string I in the riser pipe R. After the equipment is made up on a secondary, producing string, wire line, or the like, it will be necessary to reciprocate the ball element 1 to fully open position to pass the equipment through the lubricator assembly A and into the well W therebelow. With the lock mandrel 4 and its corrcsponding and associated

ment between the control mandrel and the latch sleeve; and,

Fig. 9 is a view similar to that of Fig. 8 showing the lock sleeve in position to unlock the control mandrel, with tubing pressure entering the lock piston chamber for activation of the lock sleeve.

The lubricator valve apparatus A has a ball valve element 1 which is shifted from an open position to a closed position by longitudinal manipulation of a control mandrel mechanism 2 operatively comprising a ball piston element 3, an elongated lock mandrel member 4 affixed thereto, a lock piston mandral 5 affixed to the lock mandrel member 4, and a thrust carriage element 6 engaged below the lock piston mandrel 5.

The ball valve element 1 and its adjacent operative components are depicted in Fig. 3. As shown, the ball element 1 has a flow passageway 1*a* therethrough to permit communication of well and other fluids as well as tools, such as perforating guns, and the like, not shown. The internal diameter of the ball element as represented by the flow passageway 1*a* is substantially equivalent to the internal diameter of the control mandrel mechanism 2 thereabove and bottom sub member 7 therebelow to provide a full opening valve element. The ball element 1 is manipulatively affixed to a pair of companion control rings 8 each having in its center a control seat 9 for housing of a pair of exteriorally protruding control pins 10 on the valve element 1. The control ring 8 (Fig. 3) is affixed to the inner surface 11 of a longitudinally extending valve control strap 12 having its upper end 12*a* a series of lock members 13*a* and 13*b* to assist in manipulation of the valve element 1, and a solid valve rotation stop member 14 on the control strap lower end 12*b* adjacent and just below the control ring 8. The valve rotation stop 14 has primary and secondary surfaces 14*a* and 14*b* on each side thereof for limitation of the rotation of the ball element 1 during reciprocation. The primary surface 14*a* of the valve stop element 14 will engage a companion shoulder stop element 15 extending from a travel grooveway 10*a* formed around the control pin 10 on each side of the ball element 1. When the ball element 1 is manipulated to its closed position, the control pin 10 will rotate within the control ring 8. The ball element grooveway 10*a* will rotate with respect to the valve stop element until the secondary surface 14*b* engages protruding thrust abutment 16 on the valve element 1, thereby preventing further rotation and reciprocation of the ball element 1.

The ball element 1 is operatively engaged with the valve control strap 12 when the control pin 10 is within its companion control seat 9, the valve rotation stop member 14 being within the ball element grooveway 10*a*. Additionally, the valve control strap 12 is operatively engaged within an exterior valve control strap housing 17 having therein an engrooved longitudinal control strap receptacle 18 for receipt of the valve control strap 12. Protruding from the inner diameter surface 17*a* of the valve control strap housing 17 is a valve manipulating pin 19 for travel engagement within its companion manipulating slot 20 on the exterior surface of the ball element 1. As the pair of valve control straps 12 are caused to be raised or lowered, the ball element 1 is rotated by the force exerted by the manipulating pins 19 over outwardly extending surfaces 21 of the slots 20.

The ball element 1, valve control strap 12 and control strap housing 17 are, in turn, housed within the apparatus A in a circumferentially extending elongated valve housing member 22 connected at its lower end by threads 23 to the bottom sub members 7, which, in turn, has at its upper end an upwardly protruding head 24 with a pluarilty of portal members 25 providing pressure passageways from the interior of the apparatus A to a pressure passage 26 adjacent the head portion 24 of the bottom sub 7 and the valve control strap housing 17, for permitting pressure communication within the apparatus A during the reopening sequence of the ball element 1, as described below. The bottom sub 7 is connected at its lower end by thread members 27 to a tubing section 28 which continues the tubing string downwardly through the well W (Fig. 1). O-rings 29 are provided within their respective grooveways 29*a* on the bottom sub 7 and the upper portion 30 of the tubing element 28 to prevent fluid communication between the tubing section 28 and the bottom sub 7, and the bottom sub 7 and the valve housing 22.

The upper and lower outwardly extending carriage lock elements 13*a* and 13*b* of the valve control strap 12 are functionally engageable within a companion grooveway 13*a*' within the thrust carriage 6, and above an outwardly and circumferentially extending abutment 13*b*' upon a differential sleeve 31, respectively. The differential sleeve 31 has protruding exteriorally thereabout, but not fixed thereto, a retainer ring element 32 encapsulating at its lower end an elastomeric elongated seal member 32*a* for smooth engagement upon the outer smooth surface 1*b* of the ball element 1. Within the retainer ring 32 is a grooveway 32*b* for receipt of an O-ring 32*c* to prevent fluid communication between the retainer ring 32 and the differential sleeve member 31. The differential sleeve 31 is a free-floating device, except when the valve is in the fully closed position, the valve being operatively

engaged by the valve control strap 12 to the thrust carriage 6 immediately thereabove which, in turn, is engaged by threads 33 to the lock piston mandrel 5. The mandrel 5 has at its upper end a series of pressure ports 34 for communication of fluid within the interior of the apparatus A to within a releasing piston pressure chamber 35 formed between the lock piston mandrel 5 and a releasing piston 36 outwardly encircling the adjacent upper end thereof. The lock piston mandrel 5 is connected by threads 37 to the lock mandrel 4 which, in turn, provides a partial internal housing for the locking device described below. The lock mandrel 4 is engaged at its upper end by threads 37' to the ball piston 3 having a grooveway 38*a* for receipt of the circumferentially extending O-ring 38 around the upper end of the lock mandrel 4 to prevent fluid communication between the ball piston 3 and the lock mandrel 4. The lower portion of the ball piston 3 provides an exteriorally protruding retainer stop member 39 having engaged on the top thereof a spring seat 40 engaging the lower end of a spring element 41 encircling the lower portion of the ball piston 3, the spring element 41 being encapsulated at its upper end by a companion spring seat 42 encircularly affixed around the ball piston 3 and held in place against upward travel by an outwardly extending and downwardly facing shoulder 43 formed on a control pressure housing 44 described in further detail below.

Forming the uppermost portion of the ball piston 3 is a longitudinally extending piston head 45 having a grooveway 46*a* for receipt of an O-ring 46 at each end of its upper and lower ends to prevent fluid communication between the piston head 45 and the control pressure housing 44. A similar grooveway 47*a* for receipt of companion O-ring 47 also is provided upon the piston head 45 to prevent fluid communication between the piston head 45 and a top sub 48 when the piston head 45 slides along the outer and inner surfaces 49*a* and 49*b* of the top sub 48, and control pressure housing 44 respectively, during operation. The piston head 45 has at its upper end a central opening 50 entering into a pressure passageway 51 extending longitudinally throughout the piston head 45, the passageway 51 terminating at a corresponding opening 52 at the lower end of the piston head 45 and communicating with a pressure chamber 52*a* formed therebelow by the lower end of the piston head 45, the inner wall 44*a* of the control pressure housing 44, the outer wall 3*a* of the ball piston 3, and continuing lowerly between the outer housing 13 of the apparatus A and the control mandrel components 2 until pressure communication resistance is afforded by operation of the O-rings within the control pressure housing 44, the lock piston housing 54, the releasing piston 36, the lock piston mandrel 5, and the lock mandrel 4.

The piston head 45 and the passageway 51 therethrough communicate with an upper control pressure chamber 55 which, in turn, communicates with a control line duct 56 formed within the upper portion of the control pressure housing 44. A receiving groove 57 at the uppermost end of the control pressure housing 44 provides a means for engagement of the lower end 58 of a fluid control line 59 which extends upwardly and adjacent the exterior of the apparatus A to a control panel on the ship deck, platform, or the like (Fig. 1).

A reference vent line 60 extending from the control panel, of similar construction as the control line 59, is engaged within a companion receiving groove 61 therefor within the upper end of the control pressure housing 44 and at a point 180° from the receiving groove 57 for the control line 59. The reference vent line 60 communicates with a reference pressure duct 62 longitudinally and downwardly extending therefrom within the control pressure housing 44 and terminating at a lower port 62*a* which is in fluid communication with a reference pressure chamber 63 circumferentially extending around the piston head 45 and within the upper portion of the control pressure housing 44. The reference pressure varies in the chamber 63 to offset the hydrostatic pressure of control fluid in control line 59 which varies with depth.

When the ball element 1 is in open position such that the flow passage 1*a* therein communicates with the interior passageway P and P' above and below the ball valve element 1, the apparatus A and the ball valve element 1 will not be activated until such time as control pressure is decreased, thus initiating the ball closure cycle.

In association with the ball closure cycle is the function and operation of the locking system which prevents downward longitudinal movement of the lock mandrel 4 and its interconnecting and associated parts until such time as tubing pressure causes deactivation of the locking system. The locking system of the present apparatus basically is comprised of a longitudinally extending tubular-like locking sleeve 64, the releasing piston 36 and a collet lock apparatus 65. Interconnected by threads 66 to an upwardly and inwardly extending box 67 on the housing 13 is a circumferentially extending locking latch mechanism 68 having an adjustment passage 68*a* extending laterally through its uppermost portion. At a lower end of the locking latch mechanism 68 and forming a part thereof are plurality of flexible finger-like collet members 65, each member 65 having an inwardly protruding

parts being in locked position, activation of the ball element 1 to open position can only be accomplished by increasing pressure within the tubing area P to an excess of well pressure within the tubing area P^1, acting below the valve, thus providing differential pressure to release the locking sleeve 64 and enable manipulation of the ball element 1 to open position. This assures well control because the tubing must be closed and pressure tight at the surface. Since the well pressure in area P will be greater than the tubing pressure acting within the area P^1 below the ball valve 1 during initial manipulation of the ball element 1 to open position, the differential sleeve 31 will be pressure activated into sealing engagement with the outer smooth surface 1*b* of the ball element 1 to permit the seat 31*a* of the sleeve 31 to engage the ball element 1 and surface 1*b* and establish a pressure seal. Once the ball opens, the meal-to-metal seal is no longer pressure activated and the differential sleeve 31 is no longer in contact with the ball element 1. The differential sleeve 31 serves to prevent metallic friction between the surface 1*b* of the ball element 1 and the metallic surface at the end 31*a* of the differential sleeve 31 when the ball element 1 is being manipulated to open and closed position. Additionally, the retainer ring 32 and elastomeric seal element 32*a* function in cooperation with the differential sleeve 31 to provide a rubber-to-metal seal when the well pressure in the area P^1 below the ball exceeds pressure above the ball element 1 in the area P.

In order to shift the ball element 1 from closed to open position, the tubing pressure in the area P is permitted to enter the releasing piston chamber 35 through the pressure ports 34 in the lock piston mandrel 5. As the pressure is increased over the static well pressure in the area P^1 the differential pressure in the releasing piston chamber 35 causes the releasing piston 36 and the locking sleeve 64 interconnected therewith to move longitudinally downwardly within the control pressure housing 44. As the locking sleeve 64 and the releasing piston 36 move downwardly, the spring 73 housed within the locking sleeve 64 is contracted and the outwardly protruding shoulder 71, which has engaged the collet member 65 to cooperate with the upset 70 to lockingly engage the mandrel 4, is caused to separate from the collet 65. As the locking sleeve 64 travels downwardly because of tubing increase, the collet 65 will expand and in the inner surface of its flexible elements will quickly be passed over by the outer longitudinal surface 70*a* of the upset member 70 on the lock mandrel 4. When the collet element 65 is disengaged from the upset member 72, the lock mandrel 4 and its companion activating elements will be urged downwardly by control pressure on the piston head 45 as well as by expansion of the spring 41 encircling the ball piston 3 and pressure exerted directly on the ball element 1 by fluid in the area P. The thrust carriage 6 which is affixed to the lock piston mandrel 5 urges the valve control strap 12 in a downward direction to, in turn, cause the manipulating pin 19 on the valve control strap housing 17 to travel within the manipulating groove 20 on the ball element 1 to rotate the ball element 1 to open position. Rotation of the ball element 1 continues automatically to the full open position until secondary surface 14*a* of the valve stop 14 engages the thrust abutment 16 on the surface 21 of the ball element 1. The downstream 24*a* stops longitudinal movement of the ball element 1 and its companion activating elements. When the ball piston 3 and its correspondingly operational parts are manipulated to rotate the ball element 1 to open position, the reference fluid level will drop somewhat as the ball piston head 45 travels downwardly and the ball piston chambers 55 and 63 increase correspondingly. Thus, downward movement of the ball piston 3 can be detected at the drill ship or platform surface by a drop in pressure and fluid level in the indicators affixed to the reference vent line 60. Such a drop and decrease in fluid level and pressure would be indicative that the ball element 1 is in open position. Correspondingly, an increase in fluid level in the reference vent line 60 would signify that the ball piston 3 and its correspondingly interrelated components had been activated to rotate the ball element 1 to closed position.

From the above, it can be seen that a lubricator valve apparatus is provided which is placed into closed position by a decrease in control line pressure. An increase in control line pressure thereafter will not cause a reversal in the operational mode to reciprocate the ball element to open position. Additionally, closure of the ball element also activates a locking mechanism which will prevent manipulation of the ball element to open position merely by increasing control line pressure. In conjunction with each of the above features, there is provided a means for unlocking the ball element control mechanism and allowing rotation of the ball element to open position by means of increasing tubing pressure within the apparatus. In conjunction with the utilization of tubing pressure to unlock and activate the ball element to open position, there is provided a friction reduction mechanism which provides a metal-to-metal seal upon increase of tubing pressure.

It can also be seen from the above that the lubricator embodying the present invention may be manipulated to open, closed, locked,

and reopened positions without requirement of retrieval of the lubricator to the drill ship or platform for reactvation. This feature is accomplished by utilizing control line pressure and tubing pressure in sequential combinations.

WHAT WE CLAIM IS:—

1. A valve assembly comprising: a passageway to be opened and closed by valve means sequentially to permit and prevent flow of a fluid therethrough from an upstream side of the valve means to a downstream side of the valve means; means responsive to a first control fluid, which fluid is isolated from fluid in the passageway, for causing or allowing shifting of the valve means from its open position to its closed position, and vice versa; means for mechanically locking the valve means in its closed position to prevent shifting of the valve means to its open position in response to just the first control fluid; and means responsive to a second control fluid for unlocking the locking means, and for then causing or allowing the valve means to be shifted from its closed position to its open position.

2. A valve assembly according to claim 1, in which pressure exerted by fluid flowing through the passageway on the upstream side of the valve means causes the valve means to be shifted to its closed position when pressure exerted by the first control fluid is sufficiently reduced.

3. A valve assembly according to claim 1 or claim 2, in which the locking means is unlocked when pressure exerted by the second control fluid in the passageway on the downstream side of the valve means is sufficiently increased.

4. A valve assembly according to any preceding claim, in which the first and the second control fluid responsive means include respective piston sleeves which are reciprocable, concentrically to one another, in the longitudinal direction of the passageway, and are continuously urged in opposite directions by respective mechanical biasing means.

5. A valve assembly according to any preceding claim, in which a floating differential sleeve is reciprocable along the length of the passageway on the downstream side of the valve means, the differential sleeve being urged into sealing engagement with the valve means in response to pressure differential across the valve means when the valve means is in its closed position, and the differential sleeve being sealingly disengaged from the valve means in the absence of pressure differential across the valve means when the valve means is in its open position.

6. A valve assembly according to any preceding claim, in which means for indicating whether the valve means is in its open or closed positions includes a reference pressure chamber whose volume changes with operation of the first control fluid responsive means.

7. A valve assembly according to any preceding claim, in which the passageway extends through a housing having means at each end for permitting connection with respective tubes or other members having bores therethrough.

8. A valve assembly according to claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

9. A lubricator including a valve assembly according to any preceding claim and forming an integral part of a tubing string extending from an oil or gas well.

10. A lubricator including a valve assembly according to claim 6, the lubricator forming an integral part of a tubing string extending from an oil or gas well on a sea bed, and hydrostatic pressure exerted by the first control fluid being offset by pressure exterted in the reference pressure chamber.

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Sheet 1

Fig. 1

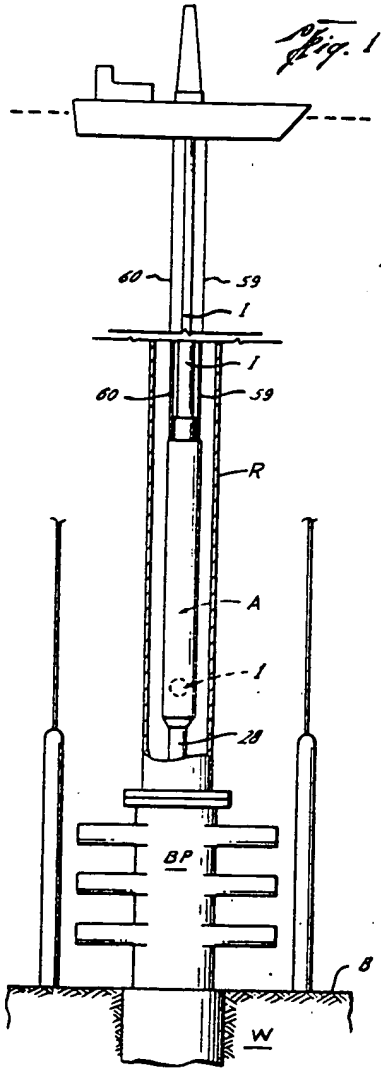

Fig. 4A

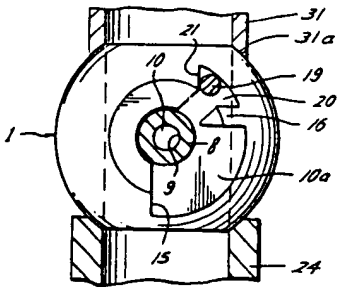

Fig. 6A

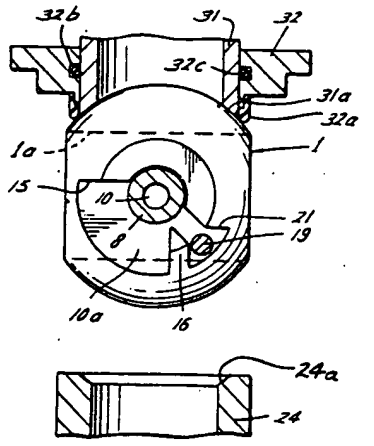

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Fig. 2A

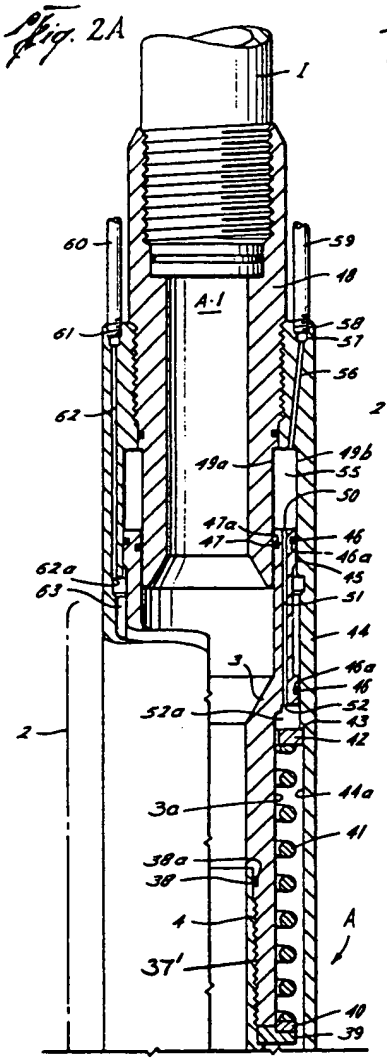

Fig. 2B

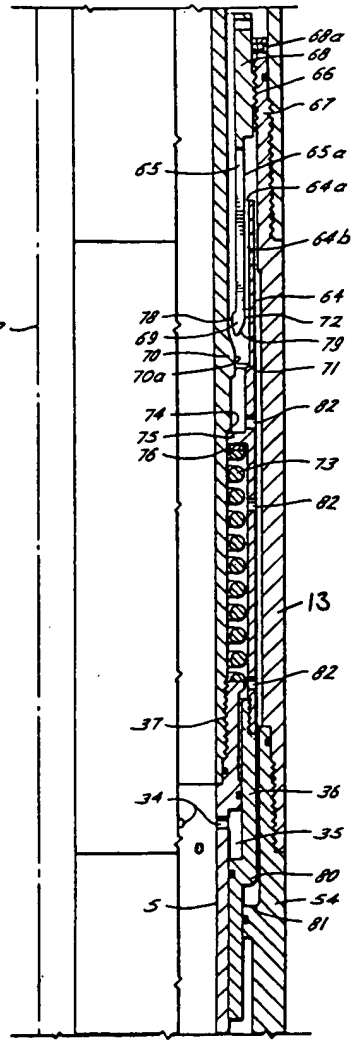

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Fig. 2C

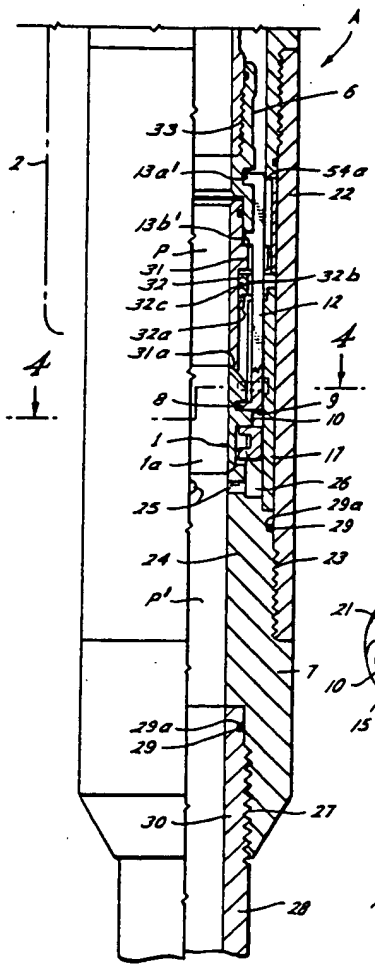

Fig. 3

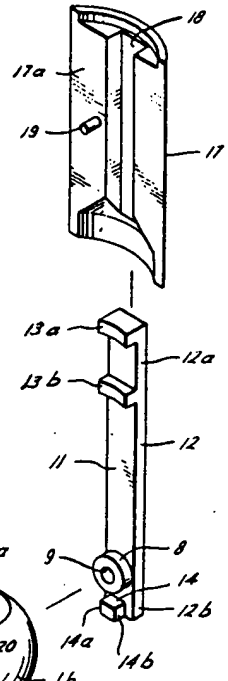

Fig. 4

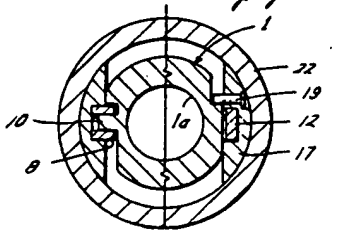

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Fig. 5A

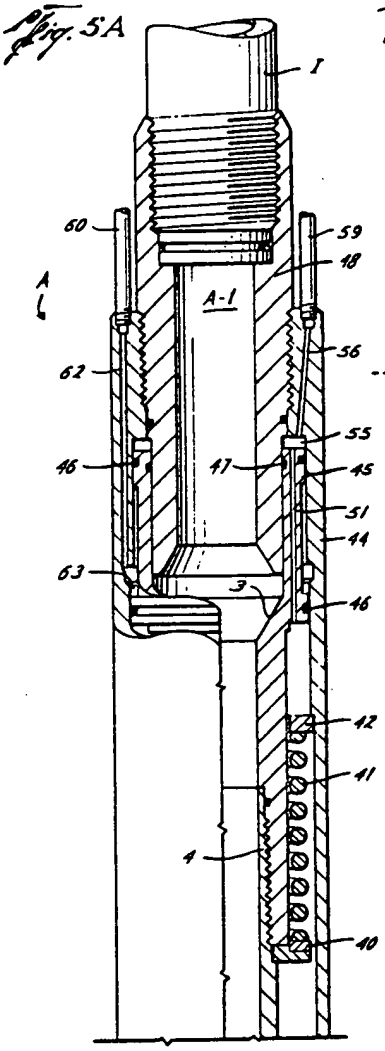

Fig. 5B

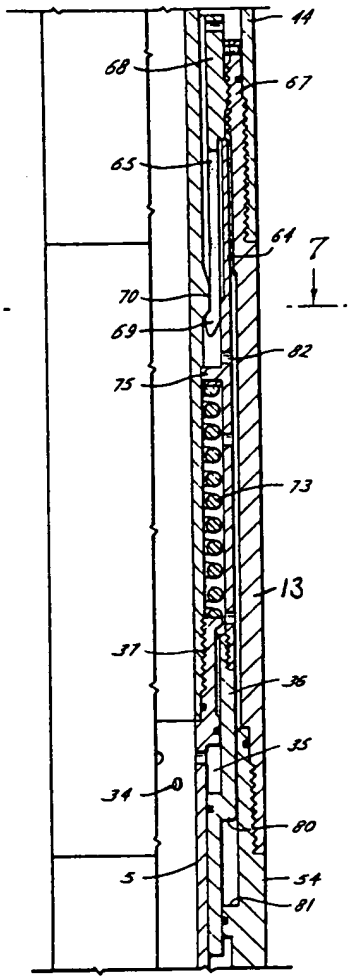

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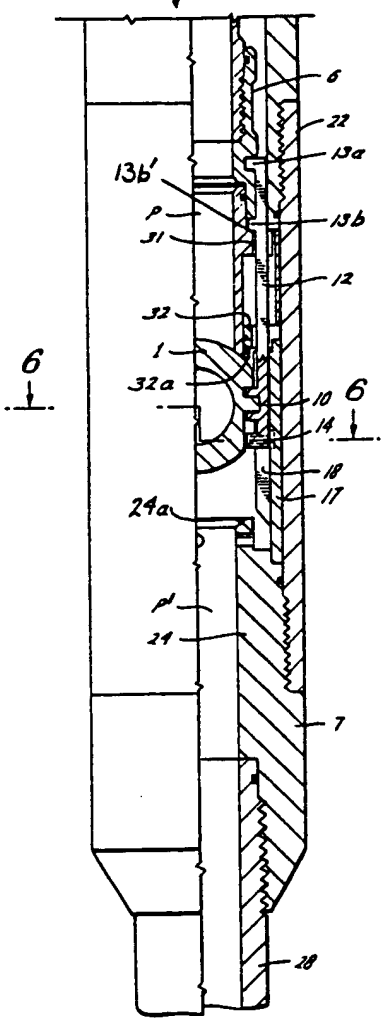
Fig. 5C



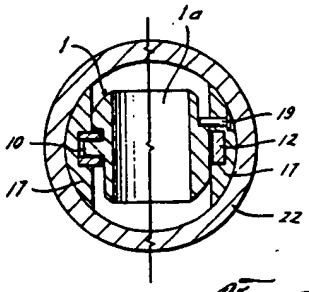


Fig. 6

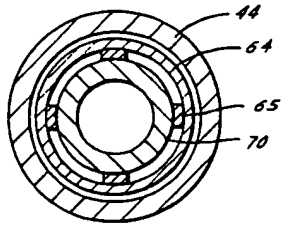


Fig. 7

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Fig. 8

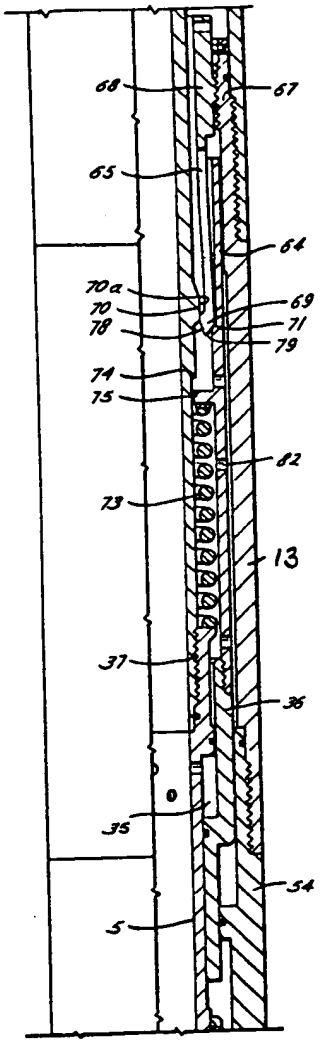

Fig. 9